

The invention relates to a multitrack read head.

Multiplexed multitrack magnetic write heads are used to record a large number of tracks (about 1000) in magnetographic printers. A write head is also known from French Patent Application 88 05592. These heads are controlled by matrix addressing, which allows the information to be recorded to be sent for example to successive columns of elementary heads, and all the heads involved in a given line to be activated by suitable excitation of the line wires.

On the other hand, the read heads which enable reading of the multitrack magnetic media recorded using these write heads are of magneto-optical type, difficult to integrate into a small volume.

A matrix magnetic read/write head is known, from the document NL-A-7 510-306, including magnetoresistive elements encased by the material of the magnetic circuits, the selection current, as well as the signal read, passing through these elements, which necessitates the production of diodes in series with each element in order to allow correct selection of the elementary heads.

The object of the present invention is a multitrack read head which can integrate a large number of elementary heads in a small volume, and whose performance is good in varied conditions of use.

The multitrack read head according to the invention includes a matrix network of elementary heads of magnetoresistive type, each comprising a magnetoresistive element in its magnetic circuit, is characterized in that at least one magnetoresistive element is inserted in series into the magnetic circuit of each elementary head, the set of magnetoresistive elements of a single column being electrically linked to a column conductor, the selection lines elementary-head consisting of conductors substantially perpendicular or slightly oblique with respect to the columns of magnetoresistive elements and passing close to the gaps of the elementary heads, a selection current being injected into the line to be selected.

According to another aspect of the invention, the multitrack read head is characterized in that, in each column, the magnetoresistive elements of the elementary heads are electrically linked to a column conductor, the magnetoresistive element being inserted in series into one of the poles of the elementary head, the matrix lines consisting of line conductors substantially perpendicular to the columns, an inhibition current being injected into the non-selected lines in order to saturate the poles of the elementary heads of these lines.

The present invention will be better understood on reading the description of several modes of embodiment, taken as non-restrictive examples and illustrated by the appended drawing [sic], in which:

- Figures 1 and 2 are simplified diagrams of connection of elementary heads of a read head according to the invention,

- Figure 3 is a diagram illustrating the variation of resistivity in a magnetic material as a function of the angle formed between the direction of the current passing through it and the direction of its magnetization,

- Figures 4 to 7 are simplified plan views of different modes of embodiment of read heads according to the invention.

The invention is described below with reference to a multitrack read head for magnetic tapes, but it is clear that it can cooperate with other magnetic media recorded using multitrack recording. Moreover, the preferred modes of embodiment of the invention relate to compact heads (to read several tens or hundreds of tracks on magnetic tapes a few millimetres or a few centimetres wide), but it is clear that the invention can also be used for much larger read heads enabling the reading of very wide magnetic media.

The read head of the invention has a matrix structure, which means that it comprises several elementary heads arranged in lines and columns. The lines are not necessarily perpendicular to the columns. The

denominations line and column are arbitrary.

In the head of the invention, the elementary heads operate using the magnetoresistive effect, i.e. they comprise a material whose resistivity varies as a function of the magnetic field to which they are subjected. To make use of the variation in the resistivity of these elementary heads, and thus obtain a signal whose amplitude is a function of the magnetic field influencing them, they are electrically connected in lines and columns and an electric current is made to pass through them, the lines of course being electrically insulated from the columns. This electric current is sent to the magnetoresistive elements of the different columns of elementary heads, the selection of one or more heads of a given line being made by applying a selection voltage or current to the corresponding line.

In the diagrams of Figures 1 and 2 the magnetoresistive elements of some of the elementary heads of a read head according to the invention have been represented: the magnetoresistive elements of the first three heads of the first two columns have been shown: T11, T12 and T13 for the first column, and T21, T22, T23 for the second column.

According to the mode of embodiment in Figure 1, in each column the elements T11, T12, T13... and T21, T22, T23... are connected in series, and each column receives a voltage V_0 .

According to the mode of embodiment in Figure 2, in each column the elements T11 etc. are in parallel, and each column receives a current I_0 .

For these two modes of embodiment, the output from each column is connected to a preamplifier A1, A2, etc.

In the mode of embodiment of Figure 1, if R is the quiescent resistance of each of the elements T11,...T23, R_e the input impedance of the preamplifiers A1, A2,..., n the number of elements in each column, the variation Δv in voltage at the input to the preamplifiers, for a variation ΔR of an element of a

column, equals:

$$\Delta v = I_0 \Delta R \frac{R_e}{nR + R_e} = \frac{I_0}{n} \frac{\Delta R}{R}$$

where $R_{eq} = \frac{nR \cdot R_e}{nR + R_e}$

This variation is therefore proportional to the measuring current I_0 and to the magnetoresistive effect $\frac{\Delta R}{R}$ of the material of variable resistivity.

Moreover, if the input impedance R_e of the preamplifiers is chosen to be sufficiently large compared with $n \cdot R$, we obtain:

$$\Delta v = I_0 \Delta R,$$

i.e. the signal level at the input to a preamplifier is practically the same as that which would be supplied by a device with only one elementary head in the column.

It can be demonstrated that the dominant noise component is the Shottky noise, a function of the measuring current. The signal/noise (S/N) ratio is then expressed by the relation:

$$(S/N) = 1/n \cdot \frac{\Delta R}{R} \sqrt{\frac{I_0}{2qB}}$$

q being the charge on the electron and B the useful passband.

It can be seen that this ratio varies with the square root of I_0 . I_0 will therefore be chosen to be as high as possible taking into account the thermal dissipation of the elements. However, this ratio also varies as $1/n$, and n must therefore be kept within reasonable limits (a few tens, for example) in order not to excessively impair the S/N ratio.

Figure 3 shows the curve of the variation in resistivity ρ of a magnetic material as a function of the angle α between the direction of the current I passing through this material and the direction of its magnetization μ . The equation of this curve is of the

form:

$$\rho = \rho_0 \left(1 + \frac{\Delta \rho}{\rho} \cos^2 \alpha \right)$$

ρ_0 being the quiescent resistivity of this material.

For a material such as Permalloy (90% Ni, 10% Fe), $\Delta \rho / \rho_0$ can reach 5%.

5 In a multitrack read head, not only the S/N ratio is important but also the crosstalk. To have access in succession to the information gathered by each of the elementary heads, a multiplexing device must be provided. For this purpose, two different processes can be used:
10 use of the non-linearity of the heads as a function of the angle of magnetization, or enabling and disabling of the heads using control currents.

 We shall first describe modes of embodiment using multiplexing by control of the angle of magnetization of
15 the heads. In Figures 4 and 5 are represented two such modes of embodiment. In Figure 4 are represented two elementary heads 1, 2 in the same column. Each head 1, 2 comprises essentially a first normal pole 1A, 2A and a second pole 1B, 2B in which has been inserted a magneto-
20 resistive element 1C, 2C. In the present case, all the magnetoresistive elements 1C, 2C, ... of the same column are made of a continuous conductor 3 of a magnetoresistive material. According to a variant mode, not shown, the different elements 1C, 2C, ... are made in separate
25 sections and connected by a layer of material of high conductivity of approximately the same size as the conductor 3.

 The poles are advantageously made using planar technology, for example as described in French Patent
30 Application 88 05592. The magnetoresistive elements, or the conductor 3, are manufactured in such a way as to render them anisotropic perpendicular to the lines of flux generated by the magnetic tape to be read, during their deposition or by a phase of post-processing, or by
35 virtue of an antiferromagnetic coupling layer. Thus, in

the absence of any external influence, the coupling between the tape and the magnetoresistive material is minimal.

5 Conductors 4, 5 substantially perpendicular to or slightly oblique with respect to the columns (3) of magnetoresistive elements, and passing close to the gaps 1D, 2D, ... of the elementary heads, constitute selection lines for elementary heads.

10 The operation of the head described above is as follows. To activate the magnetoresistive elements of a line, for example the line corresponding to the conductor 4, a current is injected into this conductor. The magnetic field thus created is insufficient to erase the magnetic tape in contact with the head, but orients the
15 magnetization of the magnetoresistive elements intersected by this conductor at 45° with respect to the direction of the line wires. By virtue of this change in orientation, the sensitivity of the magnetoresistive elements becomes a maximum and the variation in resistance produced by the field of the tape generates a
20 signal which can be measured at the output from the corresponding column.

Successive excitation of all the multitrack head selection lines thus produces, at the output from each
25 column, a signal representing successively the magnetization of the tape read by each of the elementary heads of a column.

The selection signal can be a current pulse (I_{sel}) or an alternating current successively taking the values
30 $+I_{sel}$ and $-I_{sel}$ during one or more periods.

According to the mode of embodiment represented in Figure 5, in each line of elementary heads, for example line 6, partially shown in Figure 5, the poles of the various elementary heads 7, 8, 9... are connected in
35 series, a non-magnetic conducting material filling the gaps 7A, 8A, 9A... of these heads. The magnetoresistive elements 7B, 8B, 9B... of the heads 7, 8, 9... are inserted into one of the two pole pieces of each head. In each line, the pole pieces and the material in the gap

serve as electrical conductors joining the magneto-resistive elements.

According to a variant, not shown, magneto-resistive elements are inserted into each of the pole
5 pieces of each elementary head.

According to another variant, not shown, the poles of the elementary heads are themselves made of a magnetoresistive material. In this case, the poles are in contact with the magnetic tape to be read only in the
10 vicinity of the gap.

In all the modes of embodiment, the characteristics of the magnetic circuit of the elementary heads (shape and dimensions of poles, permeance of the magnetoresistive element, etc.) are such that the selec-
15 tion current is able to orient the magnetization of the magnetoresistive element in a suitable way, without generating a field of too high an amplitude in the gap of the heads.

As mentioned above, the multiplexing of the elementary heads can be performed by controlling the
20 permeance of these heads. The control (or modulation) of the permeance of magnetic heads is known per se, in particular to form read heads operating in accordance with the "flux-gate" principle. In addition, according to
25 French Patent Applications 89 08015 and 89 09887, solutions are known to the problem of the control of multitrack write heads, in particular processes for controlling the heads by pole saturation.

In Figure 6 is shown a mode of embodiment of a
30 read head operating by modulation of the permeance of the magnetic circuits of its elementary heads. The read head comprises pole chips with substantially square surface, arranged in rows and columns, the rows of which can be perpendicular or approximately perpendicular to the
35 columns. The chips are referenced respectively P11, P12, P13,... for the first column, P21, P22, P23,... for the second column, etc. In each column, each chip is connected to each adjacent chip by two "bridges" of magnetic material, each approximately "V"-shaped with a slightly

flattened point, the two "Vs" always connecting two adjacent chips having their points turned in opposite directions. The shape and size of the "Vs" are such that between two adjacent columns, the facing points of the "Vs" each time define a gap, which is the gap of the elementary magnetic heads. In each column of chips, magnetoresistive elements are inserted in the two branches of the "Vs" of these chips on the same side of this column, for example on the left as represented in Figure 6, these elements forming part of the same band of magnetoresistive material, or being individualized linked and which is, in columns, by material a good electrical conductivity, as for Figure 4. Each column of magnetoresistive elements is traversed by a current I_0 , as in the case of Figure 4. Line conductors L1, L2..., substantially perpendicular to the columns of chips, pass at each gap E1, E2, etc. The current I_{sel} sent into each of these line conductors is of sufficient amplitude to saturate the corresponding poles and therefore inhibit the corresponding lines of elementary heads. Only the line n of heads whose corresponding line conductor Ln is not traversed by a current I_{sel} transfers the flux of the tape read to the corresponding magnetoresistive element, and the corresponding information can then be gathered on each of the columns. The column required must simply be activated (or all the others inhibited).

In Figure 7 is represented a part 11 of a magnetic circuit enabling the direction of passage of the current through a magnetoresistive material 12 to be suitably oriented. This material 12 is in the form of a narrow rectangular band into which are inserted at least two cores 13 of a material which is a very good electrical conductor and is of the same thickness as that of the band. These cores 13 are substantially rectangular in shape. They are about as long as the width of the band 12, and their width is about 1/5 to 1/10 of their length. These cores 13 are arranged obliquely with respect to the perpendicular to the axis 12' of the band 12, at a distance from each other of less than the width of the

band 12. The angle formed between the longitudinal axis of the cores 13 and the axis 12' is for example about 45°. Thus, a current I passing in the band 12 tends to cross the elements of the band lying between consecutive
5 cores 13 obliquely to the axis 12', which gives an angle between the remaining magnetization in the direction of the band and the current which flows obliquely in the band, so as to obtain the configuration of maximum sensitivity as in Figure 3.

10 A band such as the band 12 can replace the bands 3 (Figure 4) or 7B, 8B,... (Figure 5) or 10 (Figure 6), the cores 13 being appropriately oriented taking into account the direction of the poles with respect to the bands 3 or 10 or 7B, 8B, etc.



Patent claims

1. Multitrack read head including a matrix network of elementary heads of magnetoresistive type, each comprising a magnetoresistive element in its magnetic circuit, characterized in that at least one magnetoresistive element (1c, 2c, ...) is inserted in series into the magnetic circuit (1A-1B, 2A-2B, ...) of each elementary head, the set of magnetoresistive elements of a single column being electrically linked to a column conductor, the elementary-head selection lines consisting of conductors (4, 5) substantially perpendicular or slightly oblique with respect to the columns of magnetoresistive elements and passing close to the gaps (1D, 2D, ...) of the elementary head, a selection current being injected into the line to be selected.
2. Read head including a matrix network of elementary heads of magnetoresistive type, each comprising a magnetoresistive element in its magnetic circuit, characterized in that, in each column, the magnetoresistive elements of the elementary heads are electrically linked to a column conductor (10), the magnetoresistive element being inserted in series into one of the poles of the elementary head, the matrix lines consisting of line conductors (L1, L2, ...) substantially perpendicular to the columns, an inhibition current being injected into the non-selected lines in order to saturate the poles of the elementary heads of these lines.
3. Read head according to Claim 2, characterized in that, in each elementary head, the poles are substantially in the shape of a "V", the ends of the "Vs" being linked to blocks (P11, P12, ... P21, P22, ...), the magnetoresistive elements being inserted into each branch of one of the "Vs".
4. Multitrack read head according to Claim 1, 2 or 3, characterized in that, in each column of elementary heads, the magnetoresistive elements form part of the same band of magnetoresistive material (3, 10).
5. Multitrack read head according to Claim 1, 2 or 3, characterized in that, in each column of elementary



heads, the magnetoresistive elements are individualized and linked by material which is a good electrical conductor.

5 6. Multitrack read head according to Claim 1, characterized in that, in each line of elementary heads, the magnetic circuits of the elementary heads are electrically linked in series (Figure 5).

10 7. Multitrack read head according to one of the preceding claims, characterized in that the magnetoresistive elements (12) form part of a band (11) of magnetoresistive material in which cores (13) of material which is a very good electrical conductor are included, in which cores the axis is oblique with respect to the perpendicular to the axis (12') of the band.

15 8. Multitrack read head according to one of the preceding claims, characterized in that the magnetoresistive elements are manufactured in such a way as to render them anisotropic perpendicular to the lines of flux generated by the magnetic tape to be read.

20 9. Read head according to Claim 8, characterized in that the anisotropy is obtained during deposition of the magnetoresistive elements.

25 10. Read head according to Claim 8, characterized in that the anisotropy is obtained by virtue of a phase of the post-processing of the magnetoresistive elements.

11. Read head according to Claim 8, characterized in that the anisotropy is obtained by virtue of an anti-ferromagnetic coupling layer.

30 12. Multitrack read head according to one of the preceding claims, characterized in that, as magnetoresistive element, it uses at least a part of the magnetic poles themselves.

35 13. Apparatus for reading magnetic media recorded in multitrack mode, characterized in that it includes a read head according to one of the preceding claims.